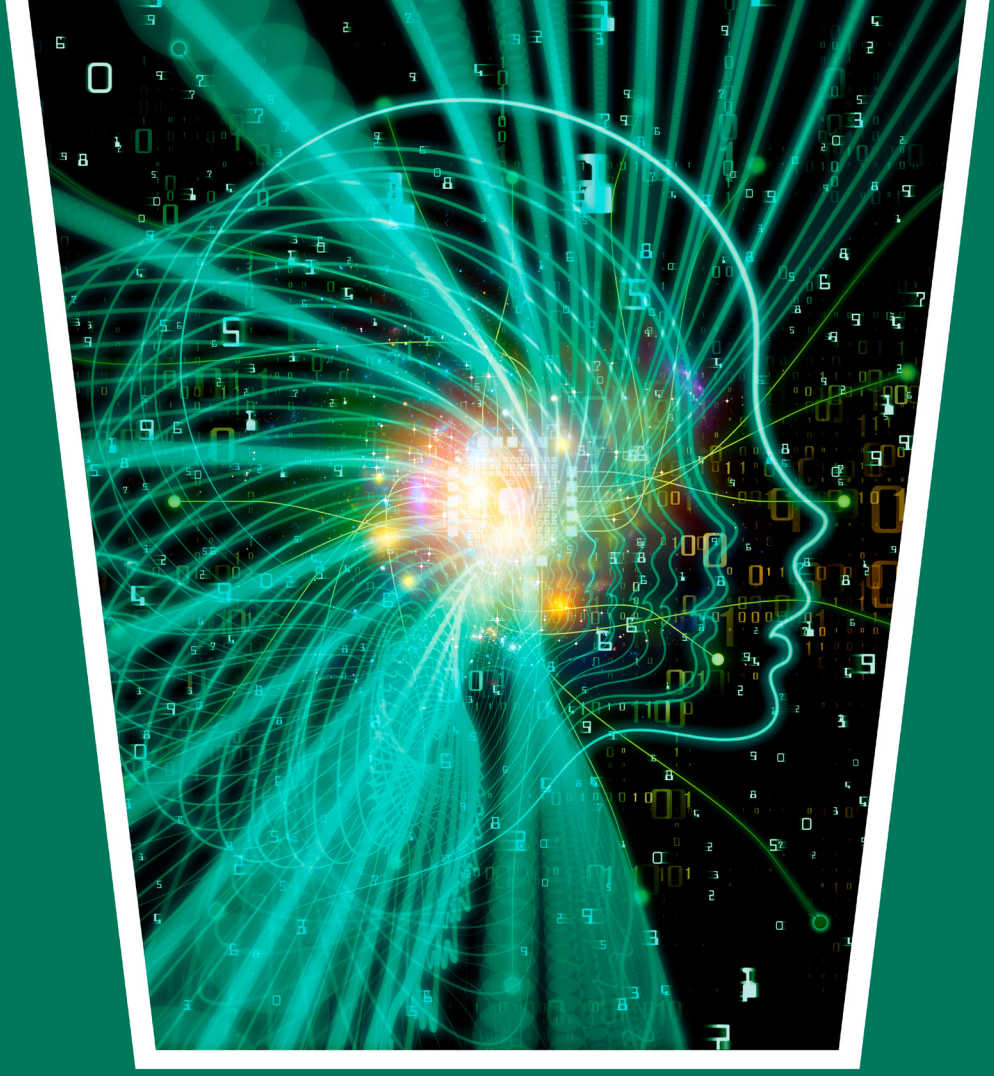

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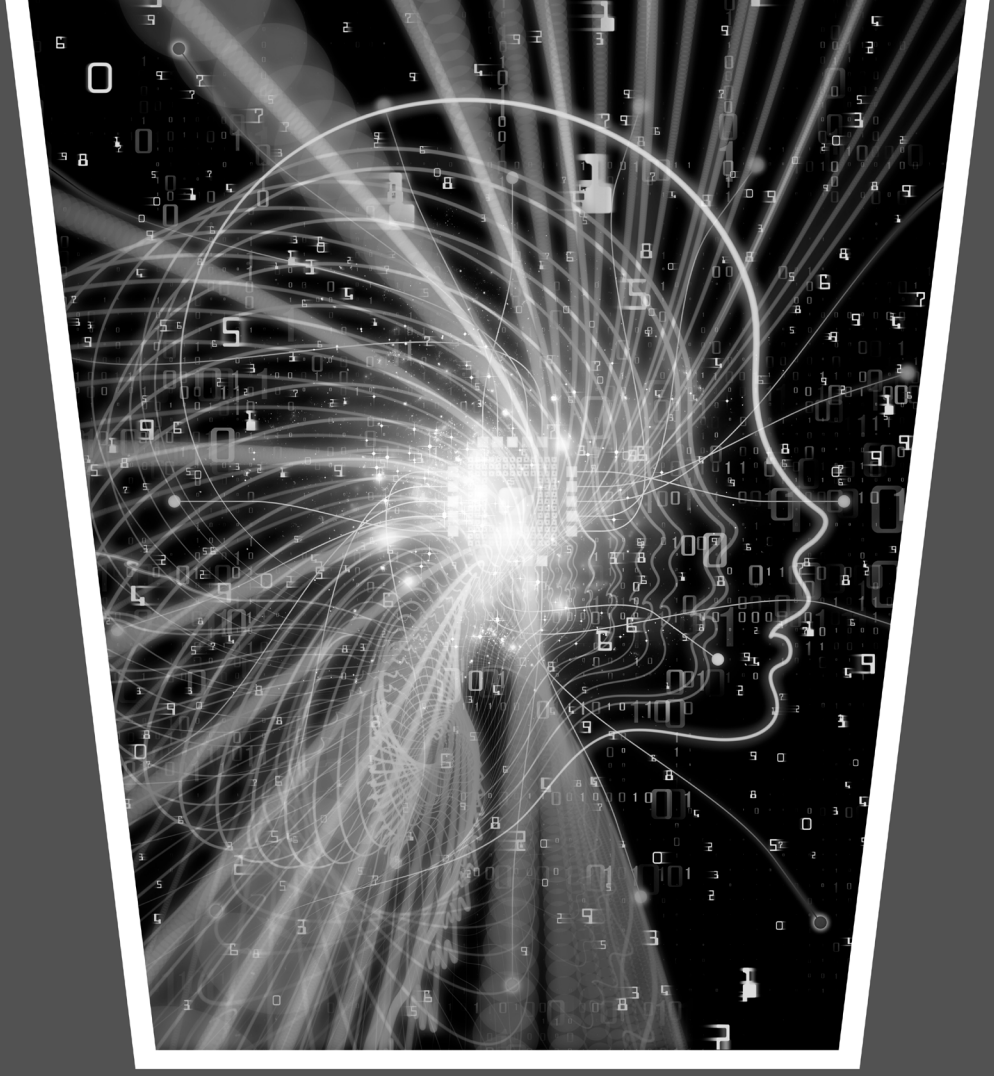

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APRESENTAÇÃO

A ciência tenta obter conhecimento sobre a estrutura fundamental do mundo utilizando observações sistemáticas e experimentais. A engenharia explora o campo do desconhecido procurando sistematicamente por novas soluções para problemas práticos. O GPS, a Internet, antibióticos, dentre outros, surgiram em meio às dificuldades das guerras. O Brasil, apesar de não estar envolvido em nenhuma, vive outras batalhas diárias.

No primeiro volume deste livro trouxemos um pouco da produção científica de um grupo de pesquisadores da região de Campinas e neste novo volume, não diferente, apresentamos mais engenharia e ciência aos serviços da sociedade e da indústria. Entretanto, desta vez a produção ocorreu durante um dos eventos de mudança mais rápida observada na sociedade recente: a quarentena imposta pela pandemia de COVID-19.

O ano de 2020 será lembrado por todos como o ano mais atípico das nossas vidas. O distanciamento social afastou pesquisadores do contato diário com colegas e de seus materiais de trabalho. Pesquisar de casa parecia impossível. Vimos ao longo de 2020 que nossos alunos conseguiam fazer pesquisa nas empresas que trabalhavam. Que, com os devidos cuidados, poderíamos usar os laboratórios. Que a internet aproximou os distantes grupos de pesquisa. Que ciência se faz com pessoas dedicadas e apaixonadas pelo trabalho.

Pesquisamos. E este livro é a amálgama do árduo trabalho de produzir ciência e tecnologia em 2020. É a flor do mandacaru: aos olhos de quem vê, surgiu no ambiente aparentemente improvável e inóspito. O ano que passou fortaleceu nosso grupo de pesquisa e parcerias foram criadas e/ou fortalecidas. Reforçamos, porém, que este livro está mais para um *tweet* diante do livro que foi 2020. Um ano longo, com muito aprendizado, muitas quebras de paradigmas e que de certa maneira, parece ainda insistir em estar entre nós. Este livro foi um recorte das nossas vidas acadêmicas, uma lembrança que será registrada nos anais da academia, mas com significado muito particular para cada um dos autores que aqui depositaram as lembranças do que melhor fizeram neste período.

O ano que se adentra rapidamente traz a esperança de renovação, de mudanças não mais tão bruscas e de um ano que se inicia em regime laminar. E nesta correnteza que é a vida, celebramos neste volume trabalhos que envolvem inteligência artificial aplicada (inclusive para a COVID-19), aplicação ou desenvolvimento de materiais, melhorias de processos industriais e da gestão de linhas de produção, geração de energia, dentre outros temas.

Finalmente, agradecemos a Editora Atena por abraçar esta iniciativa, abrindo as portas para a divulgação do conhecimento para a comunidade científica e a sociedade.

Filipe Alves Coelho

Monica Tais Siqueira D'Amelio

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SUMÁRIO

CAPÍTULO 1

THE INFLUENCE OF MEDICAL IMAGE ANALYSIS FOR COVID-19 AS A TECHNOLOGICAL MECHANISM TO SUPPORT THE GLOBAL PANDEMIC

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ABSTRACT: Imaging tests have been instrumental in understanding the effects of SARS-CoV-2 (COVID-19) on the human body and even in helping to treat the disease. The symptoms of the disease have been similar to other respiratory infections, so imaging tests have been used only as a complement to the diagnosis. The most suitable exam is High-Resolution Computed Tomography (HRCT), which is used with intravenous contrast media, in general, except for specific situations to be defined by physicians. Chest radiography is also an important imaging method that can be used to assess lungs and possible damage, since the machine can be cleaned more easily and even used on the bed (portable devices), thus avoiding the patient's displacement. The importance of these tests is the possibility of observing the effects of the new coronavirus on the respiratory system. Patients contaminated by COVID-19, can develop the most severe form of the disease thus damaging the entire lung anatomy. Even a simple chest X-ray is able to reveal the opacity aspect of the multifocal air space, called the ground-glass aspect. This chapter aims to provide an important scientific contribution related to the discussion and overview of Medical Image Analysis, its applications and influence with respect to COVID-19 in the current era, as well as to categorize and synthesize the potential of technology as a Technological Mechanism to

support current and future global respiratory virus pandemics.
KEYWORDS: Digital Image Analysis, Machine Learning, Health Informatics, Computational Intelligence, COVID-19.

1 | INTRODUCTION

The COVID-19 pandemic, a disease caused by the new coronavirus, the SARS-CoV-2 variant, has caused great alarm across the globe, since the first cases began to emerge in late 2019 in Wuhan, China. However, for most patients who died of COVID-19, the pandemic disease caused by this new coronavirus, the ultimate cause of death was pneumonia, a condition in which inflammation and fluid build-up make breathing difficult (SINGHAL, 2020; SOHRABI *et al*., 2020).

This pathology receives this variant nomenclature of the expression Coronavirus disease - 19, being 19 referring to the year 2019 where there was a report of the first case of infection. This pathology is a disease caused by the new type of coronavirus and is classified as a SARS-CoV-2 variant. Due to these characteristics, it has caused great alarm worldwide, since the first cases started to appear in late 2019 in Wuhan, China. However, for the majority of patients who died of COVID-19, the final cause of death was a severe acute respiratory syndrome, where inflammation and the accumulation of fluids hinder the patient's breathing (SINGHAL, 2020; SOHRABI *et al*., 2020).

Although the majority of those infected with COVID-19 do not develop severe symptoms, there are a considerable number of individuals belonging to risk groups, such as the elderly and those with heart disease, asthmatics, diabetics, and hypertension, who may have severe and lethal respiratory syndromes. These groups have a tendency to develop severe pneumonia, which results in the need for long hospital stays in the Intensive Care Unit (ICU), as these groups need help with mechanical breathing to survive (JIN *et al*., 2020).

In this scenario, the biggest concern pointed out by the medical community is related to the speed of spread of the virus, since the identification and isolation of infected people reduce the circulation of the virus mainly in public places of great crowding of people. In this process, the use of agile and effective methods for medical diagnosis is essential, only in this way is it possible to correctly distinguish patients with COVID-19 who are likely to need more supportive care at the hospital from those who could be monitored at home. Given this context, medical areas have allied with techniques related to telemedicine and Artificial Intelligence (AI), which has been used to assist in the diagnosis of lung injuries present in imaging studies (SOHRABI *et al*., 2020; ITO, IWANO, NAGANAWA, 2020).

The use of AI occurs in a scenario in which both asymptomatic and symptomatic patients (difficulty breathing, cough, chest pain, fever, among others) seek medical attention. Both can be submitted to a chest X-ray, where the first analysis of the exam can be performed by the AI, which looks for precursor signs of injuries or injuries of varying severity. Subsequently, these reports with suspected lung damage can be reassessed by a specialist (NGUYEN, 2020).

In this way, techniques associated with machine learning can favor radiologists and

they, at the same time, can improve learning systems, as a database created and classified by experienced professionals greatly adds quality and reliability to medical reports. On the other hand, exams with prior analysis by computer learning techniques can soften the working hours of professionals who often work several hours a day amid the pressure and nervousness involved in the hospital environment, especially in times of pandemic (MCCAL, 2020).

In this respect, image processing and analysis technology have its importance related to image exams, especially radiography and Computed Tomography (CT). Image processing techniques were originally developed to address spatial, terrestrial, and space exploration interests, only in 1970 did they begin to be used in medical images. At that time, the computed axial tomography (CAT), also called computed tomography (CT), was invented, which is one of the most important events in the application of medical diagnostic imaging. CAT is a process in which a detector ring surrounds an object (or patient) and an X-ray source connected to the detector ring, which is rotated over the object. X-rays, in turn, pass through the object and are collected by the ring detectors. Tomography consists of algorithms that use the data obtained to build an image that represents a portion through the 3D object (MONTEIRO, 2019).

Tomography was invented by Sir Godfrey N. Hounsfield and Professor Allan M. Cormack, who won the Nobel Prize in medicine in 1979 for their invention. It is important to note that the X-ray was discovered in 1895, by Wilhelm Conrad Roentgen, who received the Nobel Prize in physics in 1910. From inventions like these, 100 years later they led to the most active application in the image processing areas of the day current (NICHOLLS, 2019).

Another example is seen from the main uses of images based on gamma rays used in nuclear medicine. The approach consists of injecting the patient with a radioactive isotope that emits gamma rays and observing its decay. The images are produced by collecting the emission of gamma rays by the detectors. The principle is the same as X-ray and tomography (MONTEIRO, 2019; NICHOLLS, 2019).

Therefore, Digital Medical Image Analysis and Artificial intelligence, as Deep Leaning, show evidence that this approach can be a powerful tool for healthcare providers to provide more reliable and earlier resources in diagnosing COVID-19 and other pathologies (SHI, et al., 2020; MONTEIRO, et al., 2020; FRANÇA, et al., 2020). This chapter has the mission and objective of providing an updated overview of Digital Medical Image Analysis for COVID-19, addressing its evolution and fundamental concepts, approaching its success, with a concise bibliographic background, categorizing and synthesizing the potential of technology for that aspect.

2 | METHODOLOGY

This study was developed based on the data collection of 22 scientific articles present in bases such as Scielo, Google Scholar, and PubMed, with the scientific work dated from 2016 to 2020.

3 | THE IMPORTANCE OF TESTS TO DETECT COVID-19

CT imaging tests can be indicated as screening in asymptomatic patients, and indicated in patients with suspected COVID-19 and mild symptoms unless they are at risk for disease progression (patients over 65 years with comorbidities). CT imaging exams are too indicated in a patient with COVID-19 with moderate and severe symptoms or who have to worsen of respiratory status, still indicated for screening suspected patients for COVID-19 who have a moderate-severe clinical picture and a high probability of disease before confirmation of specific tests (LI *et al.*, 2020).

However, it is worth noting that these procedures alone are not enough to conclude dignity, it is necessary to have laboratory confirmation, even in patients who present with a clinical picture and image findings highly suggestive of COVID-19. Still pondering that pneumonia can be detected with the use of chest CT in advance, and by chest x-ray later, and tomography has greater sensitivity for the early detection of pulmonary complications (TANG *et al.*, 2020).

It is important to note that digital image processing and machine learning techniques can assist in pulmonary diagnostics, but only IgM and IgG antibody screening tests are able to detect whether the patient is or has been infected by the disease. Patients with negative IgM and IgG, do not have the disease and have had no contact with the etiologic agent. In cases of IgM positive and IgG negative, the patient has the disease, but the body has not yet started to produce the fighting antibodies. At this stage, there is a high transmission of the disease (RASHID *et al.*, 2020).

In the scenario of positive IgM and IgG, the individual is contaminated, still has a high transmission capacity, but the organism is already beginning to fight infection by means of antibodies. Those who present IgM negative and IgG positive, are the cured individuals, however, the durability of the filth naturally acquired by the individual is not yet known, and it is the person's duty to continue to follow the protocols of safety and social distance as determined by the government of each parent (RASHID *et al.*, 2020).

In cases of asymptomatic patients, there is high transmissibility of the disease, but the affected individual does not present common symptoms, such as body pain, fever, headache, loss of taste, severe symptoms, difficulty breathing, body pain, among others. These patients had IgM positive and IgG negative or both antibodies positive. The detection of these patients is paramount, since asymptomatic patients must be isolated and have medical monitoring, with a dosage of immunoglobulins and even thoracic X-rays as a way of assessing pulmonary anatomy. In some cases, patients have no symptoms, but they may have some type of lung injury, which must be monitored by the physicians (NISHIURA *et al.*, 2020).

It is important to note that COVID-19 is part of a large family of viruses that cause respiratory diseases, which has been known and cataloged since the 1960s. Mild symptoms are usually fever, cough, dyspnoea, and myalgia; however, some patients progress to SARS. However, CT may be restricted to patients with a positive test for COVID-19, with suspected complications, such as abscess or empyema. It also reports that the majority of positive patients may have normal radiographs and CT images between the first days of symptom onset. Even COVID-19 RT-PCR laboratory tests may have low sensitivity at the

onset of symptoms, so symptomatic patients with changes in chest CT may initially show negative results for COVID-19 (SINGHAL, 2020; SOHRABI *et al*., 2020).

Something in general consensus in the medical areas is that the symptoms, damages, and forms of diagnosis, as well as the correct treatment, remain obscure, thus having great variability of symptoms, presentations, developments, palliative treatments, and management protocols of patients infected by COVID – 19 (SOHRABI *et al.*, 2020).

Even so, even the moment is known and accepted by medical and scientific communities that the initial CT findings include bilateral peripheral ground-glass opacities that predominate in the lower lobes, representing that these changes are more typical of a pattern of some type of pneumonia. Considering that bilateral findings are more typical, the unilateral finding does not rule out the possibility of COVID-19, especially at the onset of symptoms. As a consequence, the disease progression presents alterations such as mosaic paving, that is, ground-glass opacities (tend to have a geographic distribution) associated with the thickening of the interlobular septa and intralobular lines, and even in areas of parenchymal consolidation, on average with a peak from the second week of the evolution of the disease, tending to reduce the dimensions and quantity of the lesions in approximately 1 month (ZHOU *et al*., 2020; ZHAO *et al*., 2020).

In some cases, an inverted halo (RHS) signal is found, characterized by opacity in oval ground glass, bounded by consolidation, that is, a rounded focal area with attenuation in ground glass surrounded by a complete or partial consolidation ring. Or even pleural effusion, tiny sparse nodules, and lymphadenopathy occurring in a very small number of cases and suggesting bacterial superinfection or another diagnosis (usually COVID-19) (ZHOU *et al*., 2020; ZHAO *et al*., 2020).

These data suggest that CT findings are similar to other respiratory viral diseases such as SARS and MERS (Middle East Respiratory Syndrome), demonstrating the absence of cavity lesions, pleural effusion, and lymphadenopathy, demonstrating that CT is possible monitoring residual fibrotic changes. However, it is worth noting that the findings of Covid-19 infection are not specific and overlap with other more common acute infections (Influenza, H1N1, among others). In this sense, it is essential, that imaging methods be used as an auxiliary tool in the diagnosis and treatment of patients (ZHOU *et al*., 2020; ZHAO *et al*., 2020, LING *et al*., 2020).

4 I THE IMPORTANCE OF COMPUTED TOMOGRAPHY (CT)

CT is a diagnostic examination at 360°, performed in a non-invasive way, producing images by a computer, via radiation, which can be analyzed from any angle. The operation is similar to the X-ray where these same rays are used to obtain images of the patient's internal parts (bones, organs, and other structures). In this sense, it can be understood that the machine that performs the tomography produces transversal radiographs, which are processed by a computer (HAAGA; BOLL, 2016; SAMEI; PELC, 2019).

This technology allows organs, structures, and tissues to be seen in more detail than the common radiography method, considering that the computed tomography devices are not used for routine examinations. This type of procedure is requested by the doctor,

depending on the case, the patient's history, and needs. Still related that the difference and even advantage between computed tomography and X-ray are that the first is more accurate, so it is more efficient in detecting injuries, fractures, or even tumors that are still very small. While the X-ray (digital radiology) takes only one radiograph of the studied site, comparatively the tomography generates 600 sections to be analyzed (HAAGA; BOLL, 2016; SAMEI; PELC, 2019).

Analyzing the exams in the context of COVID-19, the difference lies in the aspect that between radiography and computed tomography, is that the first detects pulmonary complications at a more advanced and potentially more severe stage of the disease. While tomography detects the initial stage. Still mentioning that there is no contraindication for the performance, which should be performed as soon as possible in symptomatic cases (fever, shortness of breath, among other symptoms), being reserved for hospitalized patients as well, still considering that there is no indication of performance in patients without symptoms (asymptomatic) (LING *et al*., 2020)

Thus, it is easier to obtain an early diagnosis using tomography and, consequently, achieve better results with the treatment, producing a series of detailed images of the chest. Computed tomography has started to be indicated in specific cases and with a medical recommendation, for the early diagnosis of Covid-19, since it allows that through accurate images of the chest, it is possible to evaluate the effects of the disease (ZHOU *et al*., 2020).

Commonly, at the beginning of a pulmonary infection, there are no changes in the organ, because, in the case of bacterial pneumonia, the tomographic image is left with "consolidation", consisting of a white spot in the affected area of the lung, still reporting that it aspect does not maintain the preservation of bronchovascular marks. However, with regard to COVID-19, in the so-called "phase 1", the points are seen in the most peripheral regions of the lungs, because what you see is different, it is described as a "frosted glass", in this aspect it maintains the preservation of bronchovascular marks (ZHAO *et al*., 2020).

Computed tomography is important because it is one of the most performed medical imaging procedures, and the computerized tomography device is more easily available in small towns, in general, it is half the price when compared to an MRI. Still considering the technology of the respective procedure, the reduction in radiation allowed a rapid expansion of the examination. Still reflecting that the most modern computed tomography devices capture detailed images that reconstruct three-dimensional parts of the body and provide doctors and specialists with a real view of the skeleton, lungs, and airways, in addition to other internal organs (HAAGA; BOLL, 2016; SAMEI; PELC, 2019).

5 I TECHNOLOGICAL APPLICATIONS

In the study by Lu-shan Xiao and collaborators, the Deep Learning-Based Model Using Computed Tomography Imaging for Predicting Disease Severity of Coronavirus Disease 2019 was developed and validated. between January 1, 2020, and March 18, 2020, in Honghu and Nanchang hospitals. From this study group, data from 303 patients were used in Deep Learning training and the other images from the First Affiliated Hospital at Nanchang University were used to test this multi-instance learning model and residual

convolutional neural network. The model was analyzed using a ROC curve that had an area under the curve (AUC) of 0.987 (95% confidence interval and an accuracy of 97.4% in the training set. Thus, it can be noted that the model was able to accurately predict the severity and progression of the disease (XIAO *et al.*, 2020).

Another recent study by Qianqian Ni and colleagues employs a deep learning approach to characterize COVID -19 in chest CT images. This research involved 14,435 patients, each with their respective CT images, as well as a positive diagnosis for coronavirus. The method was tested using a non-overlapping data set of 96 COVID-19 patients confirmed in three Chinese hospitals. The results obtained by the developed method were compared with those obtained by three radiology residents and two experienced radiologists as a reference standard. In this context, the F1 score, precision, specificity, and sensitivity were evaluated (NI *et al.*, 2020).

Of the 96 patients, 88 had lung lesions on the CT images, the remainder showed no abnormalities in the images. For a clinical case, the methodology showed a sensitivity greater than 1.00 and an F1 score of 0.97 in the detection of injuries by CT image in COVID-19 pneumonia patients. An average running speed of 20.3 s ± 5.8 per case demonstrated that the algorithm was much faster than the residents in evaluating images (NI *et al.*, 2020).

Another method developed was trained by means of 24.678 chest radiographs, of which 1540 were used only. These images were obtained through 454 patients with pneumonia caused by Coronavirus and through the radiological images of 223 patients with positive reverse transcription-polymerase chain reaction, and with 231 individuals with negative RT-PCR results for the pathology. The images were submitted to analysis by six readers and by the AI system. The system significantly outperformed each reader ($P < 0.001$ using McNemar's test) (MURPHY *et al.*, 2020).

6 I DISCUSSION

Still considering that radiographic images have low contrast and are difficult to read by human specialists, which can result in false diagnoses, due to the difficulty in perceiving the difference between pneumonia caused by Covid-19 or any other. Thus, after the digital technological analysis of tomographic images, together with clinical and laboratory information, it is possible to have a more grounded and coherent identification or not of alterations suggestive of the disease.

Evaluating the results present in images of this type, colors are found, which appear in gray scales, however, it plays a fundamental role in the interpretation of the images, whether using contrast or not, showing changes in the structures. In general, despite the speed in the generation of the images, i.e., the realization of the examination, the report takes a little more time, given that the material obtained undergoes a detailed human analysis. This is overcome by the experience in processing medical images and AI computerized systems to aid diagnosis, working with these images and detecting changes in the radiographic images and chest tomographies, characterizing and differentiating with greater precision and agility an image of pneumonia caused by COVID-19.

In this sense, the objective of adding the technology in this context is to make the

results of the analyzes available on the same operating platform, i.e., current medical structure without undergoing small variations according to demand, within a more useful period. Evaluating that this helps public hospitals to more efficiently screen cases and make decisions about isolation, hospitalization, and treatment.

Methods that employ digital image processing and techniques related to artificial intelligence have been increasingly opening both in the areas of industry and industry, and can be considered one of the pillars of the new industry 4.0. When used in medical fields, these technologies are often referred to as health 4.0 and generally add positively to the lives of patients and medical staff.

In this context, we can say that industry 4.0 is a strong ally in combating, detecting, and treating patients affected by the coronavirus, because it is possible to facilitate, optimize and create safer, faster, and more qualified methods than those exclusively dependent on human beings.

The interaction between man and machine tends to facilitate medical work, but equipment based on artificial intelligence is not a substitute for human labor, especially when it comes to welcoming, humanizing, and empathy. Which are important tools in the treatment of people affected by a disease that until now has no effective treatment or even vaccine.

7 I CONCLUSIONS

In the absence of specific therapeutic drugs or vaccines for the new coronavirus (COVID-19), it is essential to detect the disease at an early stage, considering within reasonable parameters such as social isolation from living with the healthy population in relation to infected people. Reflecting that the diagnosis of the infection is carried out in two stages consisting of clinical diagnosis and confirmatory diagnosis by laboratory test RT-PCR (reverse-transcriptase polymerase chain reaction), serology verifying the body's immune response to the virus by detecting IgA antibodies, IgM and IgG, or even rapid tests (antigen detecting proteins of the virus in the activity phase of the infection) and those of antibodies (identifying an immune response of the body concerning the virus).

In general, it is possible to affirm that, in the health area, AI programs provide important support to clinical decision, given their capacity to process and analyze quickly and tendency, efficiently, a large amount of data, considering that the Clinical diagnosis depends on clinical-epidemiological investigation and physical examination. Still reflecting if the patient's situation is considered, from the clinical diagnosis, a suspected case of Covid-19, the laboratory examination is now indicated. In this regard, in underdeveloped and developing countries, the benefits provided by the laboratory exam and factors related to high costs and the shortage of material are considered, which leads public authorities and hospital institutions to restrict the tests to symptomatic patients and even those with symptoms serious.

The combination of AI with medical expertise and knowledge, therefore, has the potential to considerably reduce error rates, as it is not a question of replacing healthcare professionals with intelligent systems, but recognizing the potential benefits of technology

in what it does regarding the assistance of these professionals in diagnoses and decision making, since it is essential that they are fast and, at the same time, adequate, especially in the global situation of pandemic and exponential growth of contamination.

It is precisely in this context that AI emerges in the diagnostic analysis capable of diagnosing COVID-19, in a few seconds, from the analysis of the chest tomography, with a high rate of precision. Still pondering that the analysis of a tomographic image is performed in seconds, representing almost instantly, distinguishing between patients infected with COVID-19 and those with common pneumonia or another disease. Reflecting a great advantage in coping with the pandemic, especially considering that radiologists generally need about minutes to read these images of patients with suspected COVID-19.

Or even related that the degree of lung disease detected by computed tomography of the chest, has proved to be an important aid for doctors in choosing which treatment to adopt, considering the need for follow-up in the ICU, intubation, and even hospitalization. In this way, AI diagnostic software should serve as an important support for the physician's decision making the final decision remains under the control (and under the responsibility) of the health professional.

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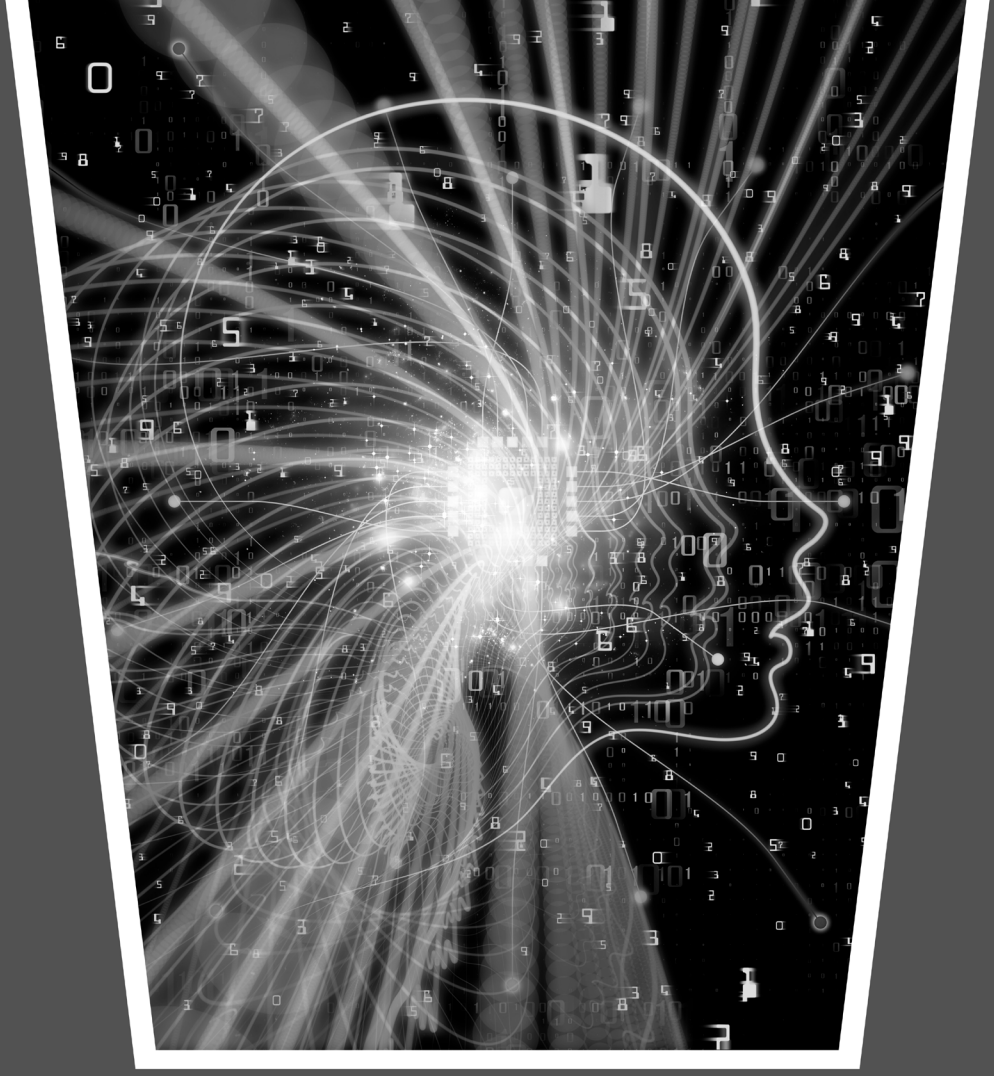

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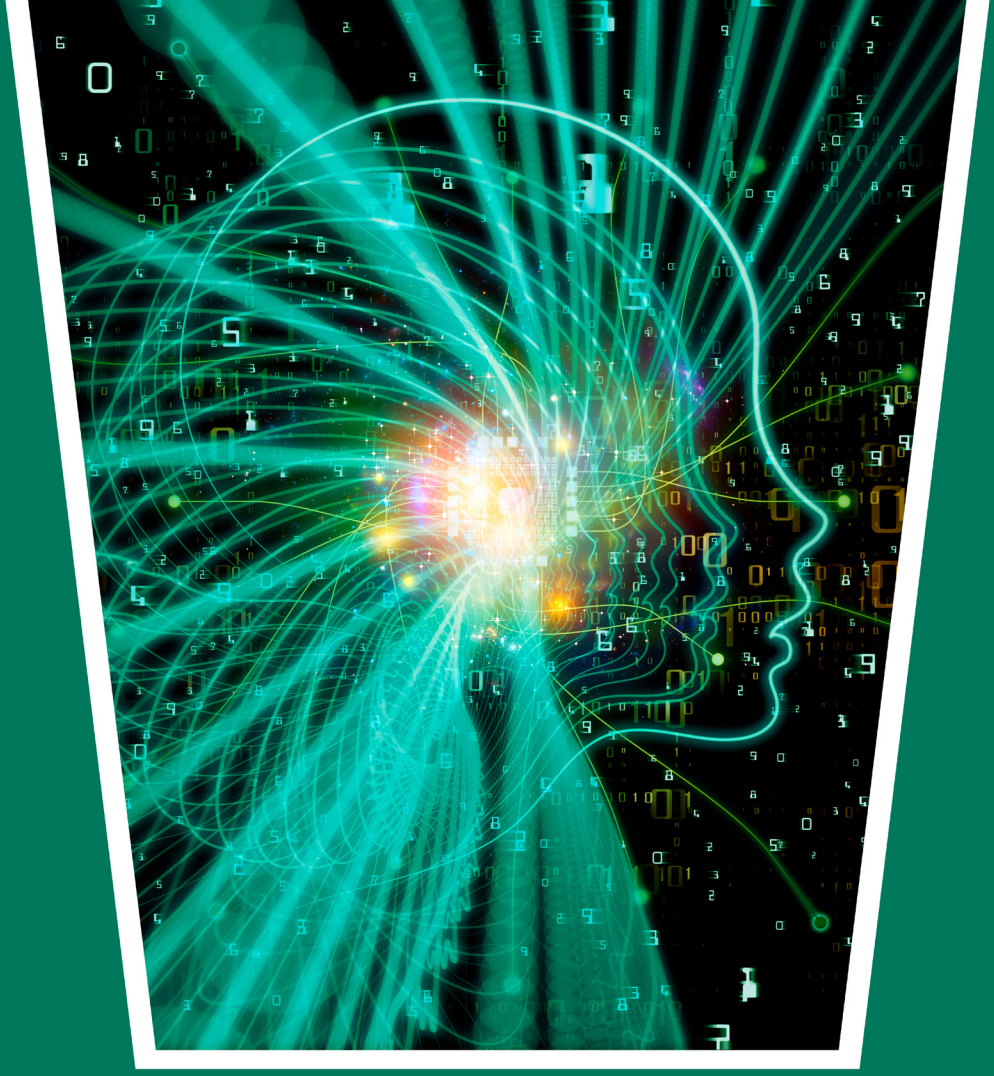

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